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Ensinger et al.

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(54) **HEATING UNIT AND CONTROL SYSTEM FOR COOKTOPS HAVING CAPABILITY TO DETECT PRESENCE OF A PAN AND METHODS OF OPERATING SAME**

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(58) **Field of Search** 219/446.1, 447.1, 219/448.11, 448.12, 448.13, 460.1, 490, 497, 507, 509, 518, 620, 621, 626

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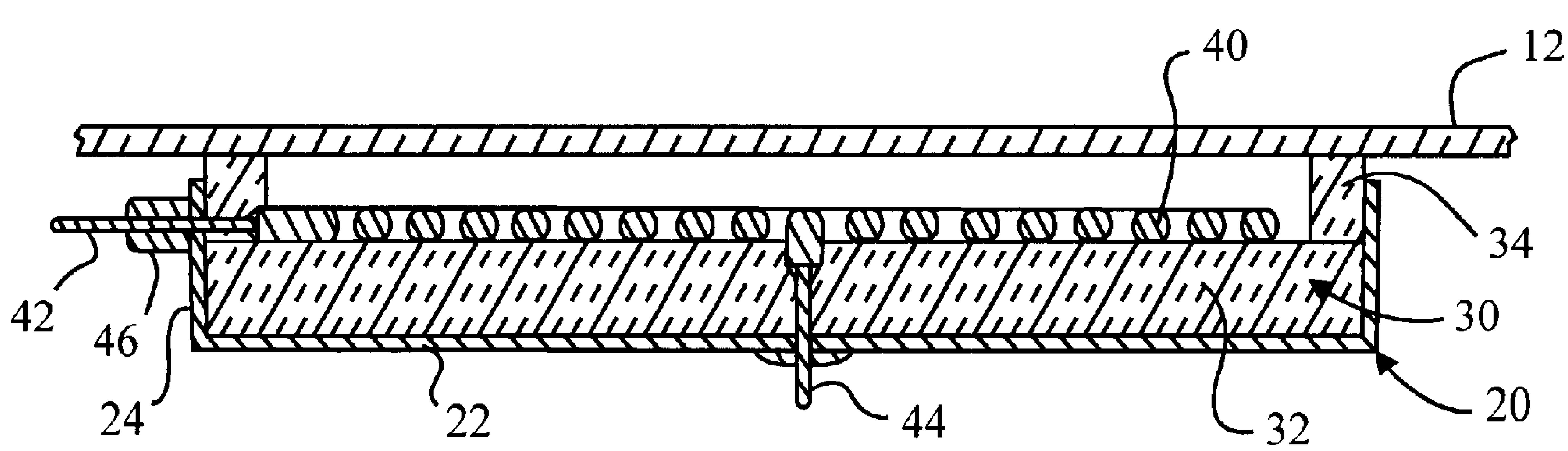
(57) **ABSTRACT**

The present invention provides a control system for a heating unit in a cooktop that is capable of detecting the presence (or absence) of a cooking pan or utensil. The heating unit has a spirally wound ribbon heater element and may be mounted below a glass-ceramic cooking surface. The control system includes a pan detection unit electrically connected to the heater element. The pan detection unit generates a high frequency signal through the heater element to determine whether a pan is present on the cooktop. The pan detection unit may have an oscillation circuit to generate the high frequency signal through the heater element. In one embodiment, the control system further includes at least one switch device that is connected between the heater element and a power source. The switch device is opened to remove the heater element from the power source when the pan detection unit generates the high frequency signal through the heater element. The present invention also includes a heating unit having dual heater units to determine the size of the pan placed on the cooktop. The present invention further includes methods of operating a heater unit and control system having the capability of detecting the presence of a pan.

34 Claims, 9 Drawing Sheets



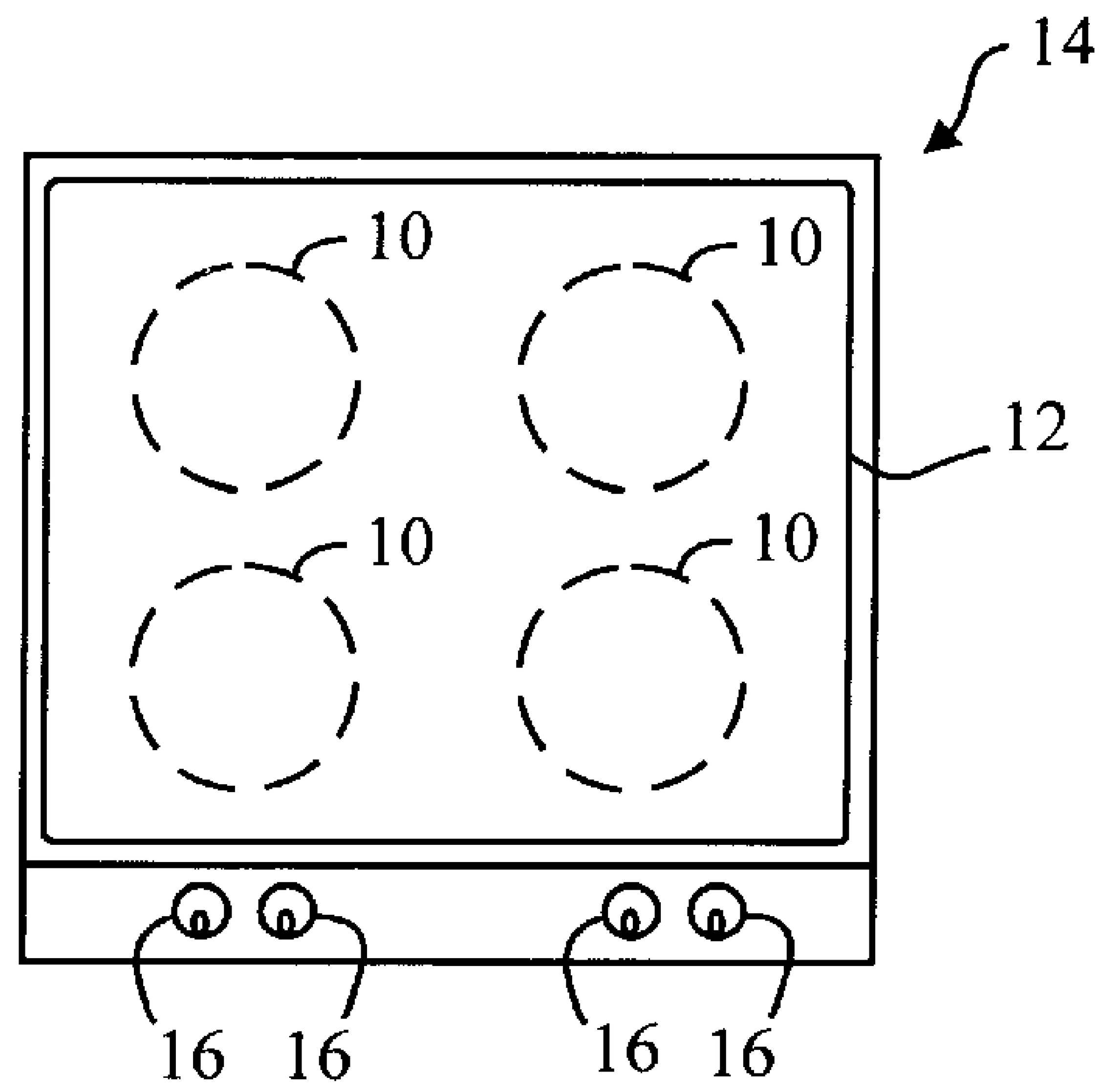


FIG. 1

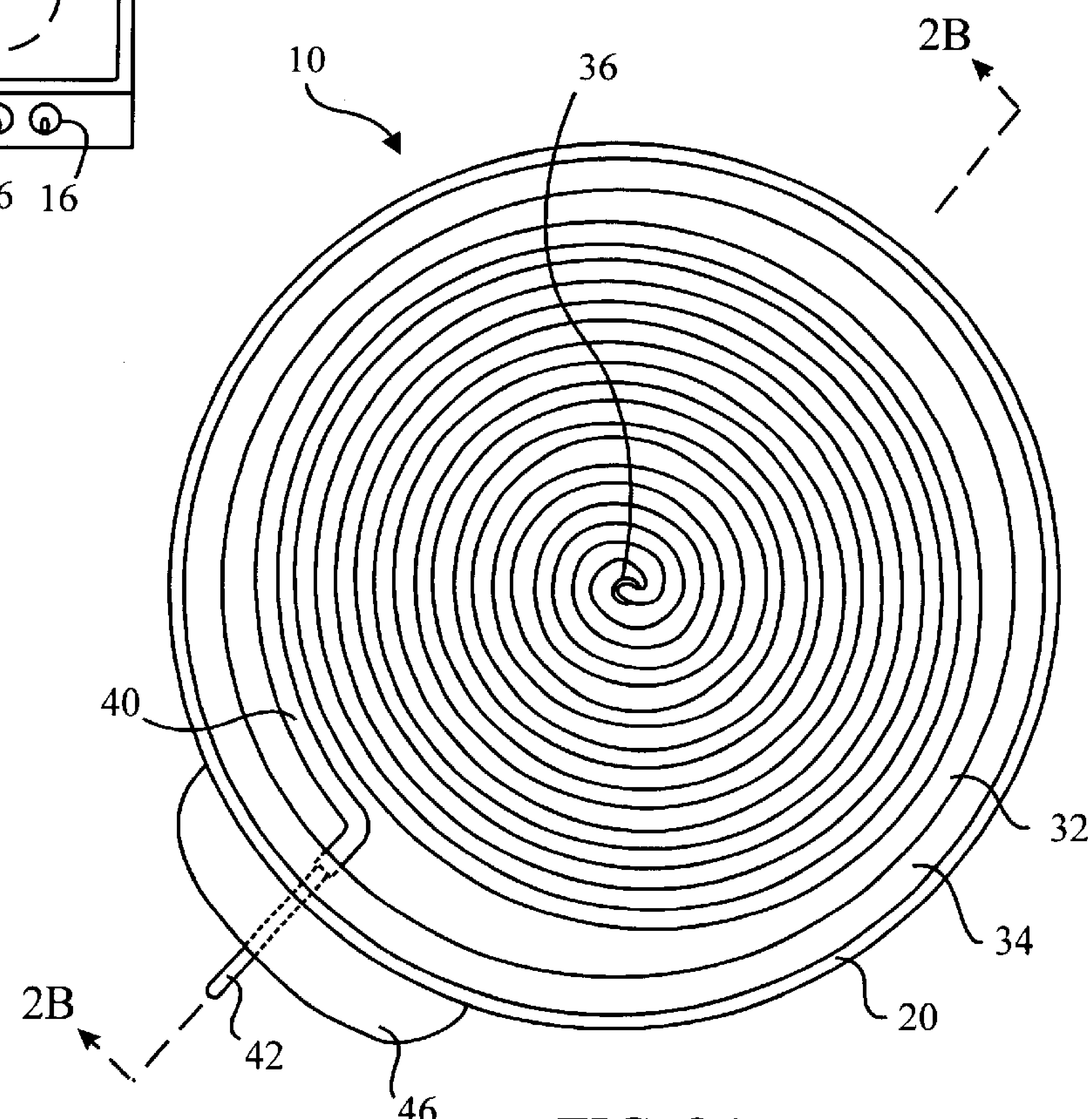


FIG. 2A

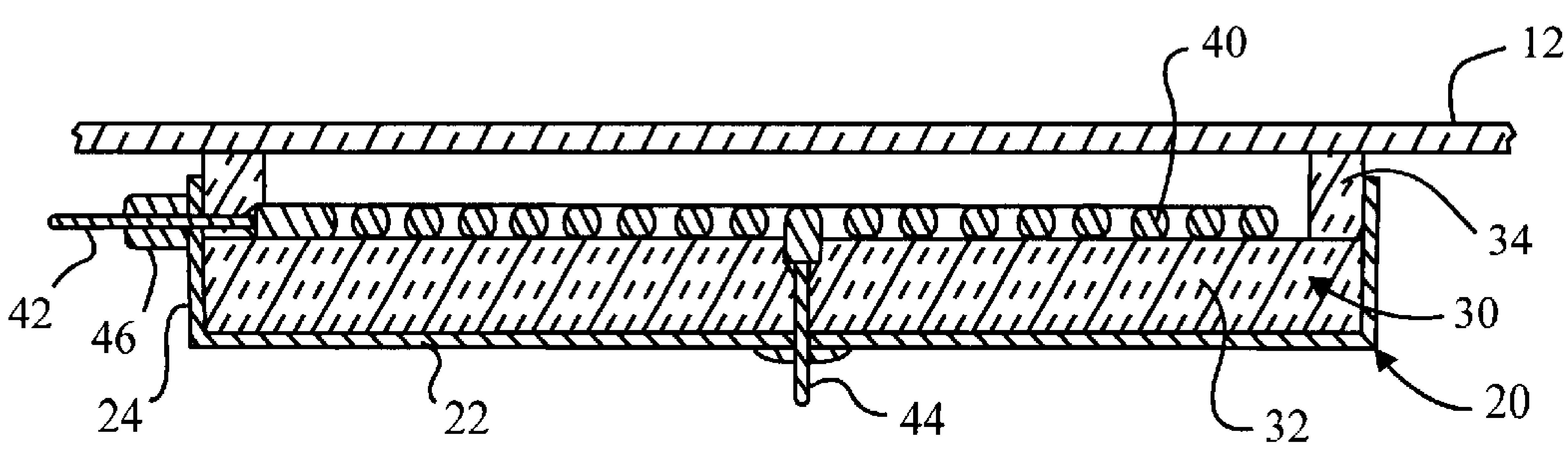


FIG. 2B

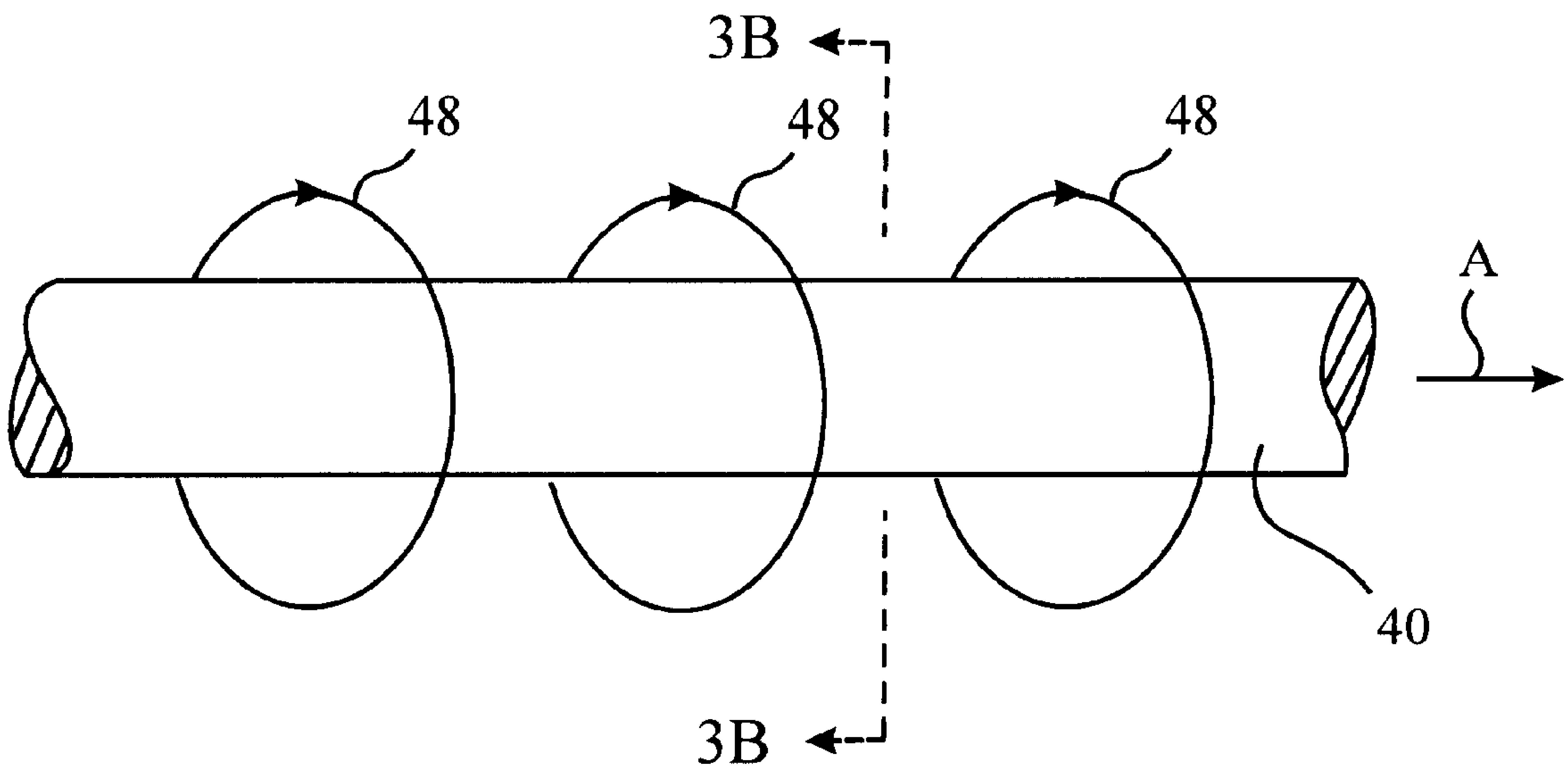


FIG.3A

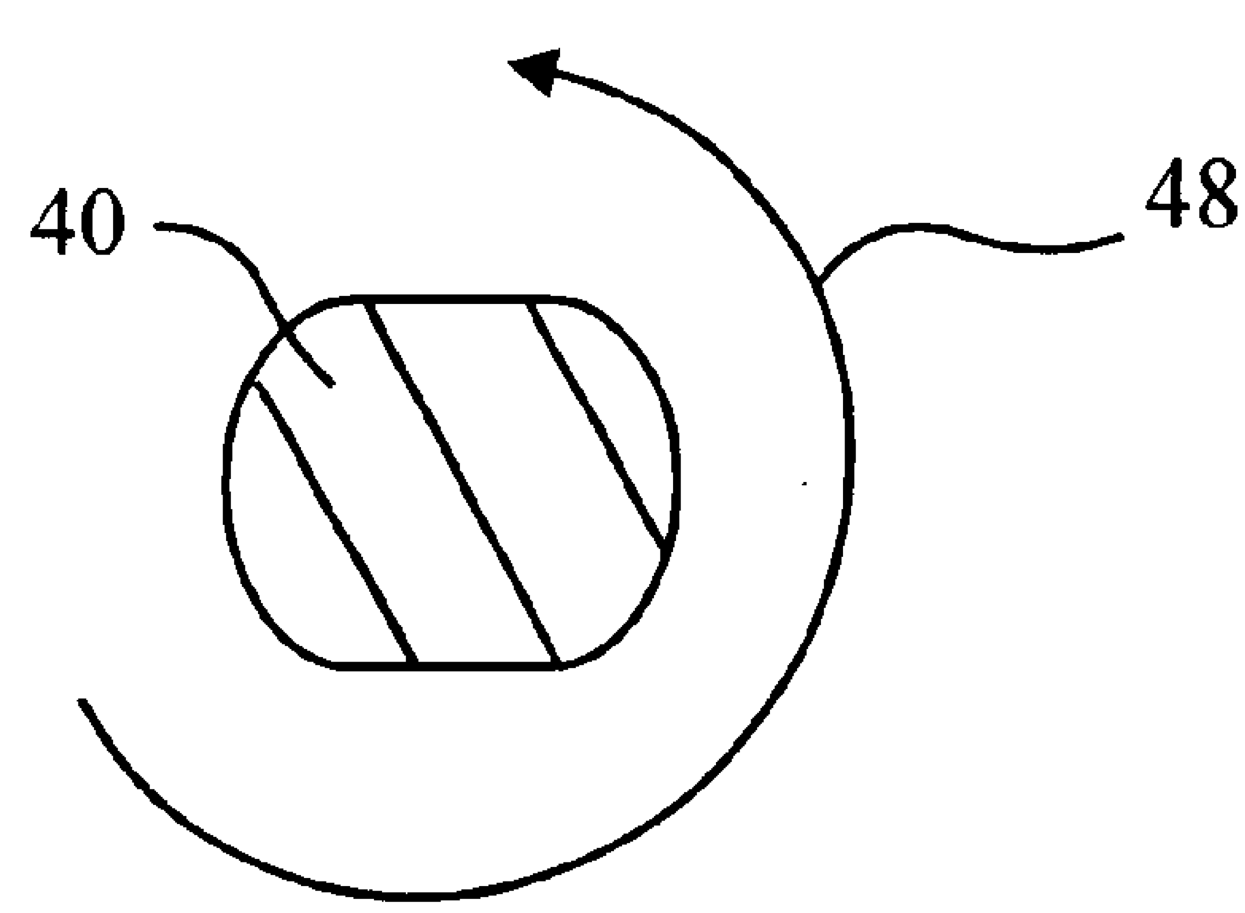


FIG. 3B

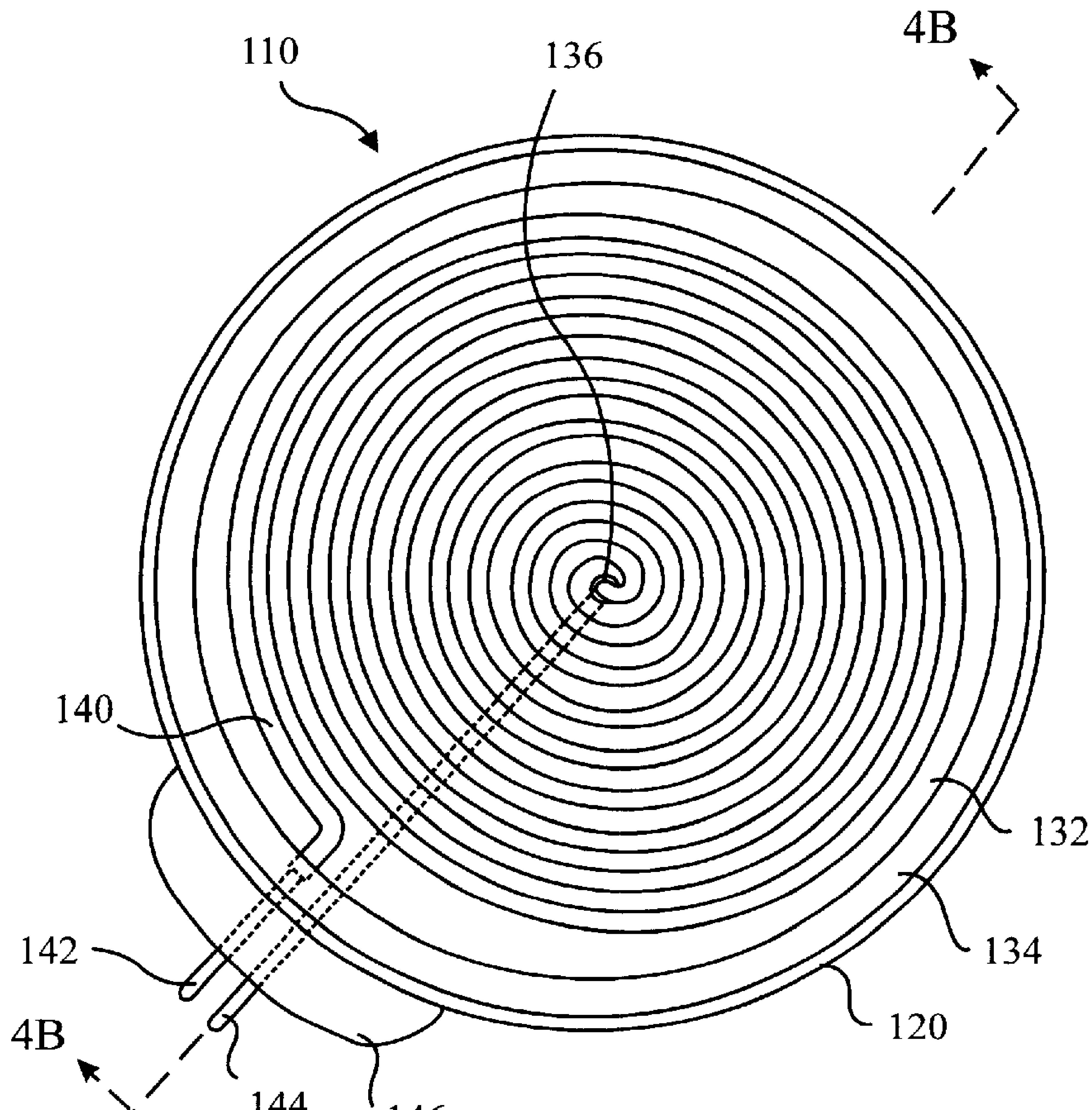

110
136
4B
140
132
134
142
120
4B
144
146

FIG. 4A

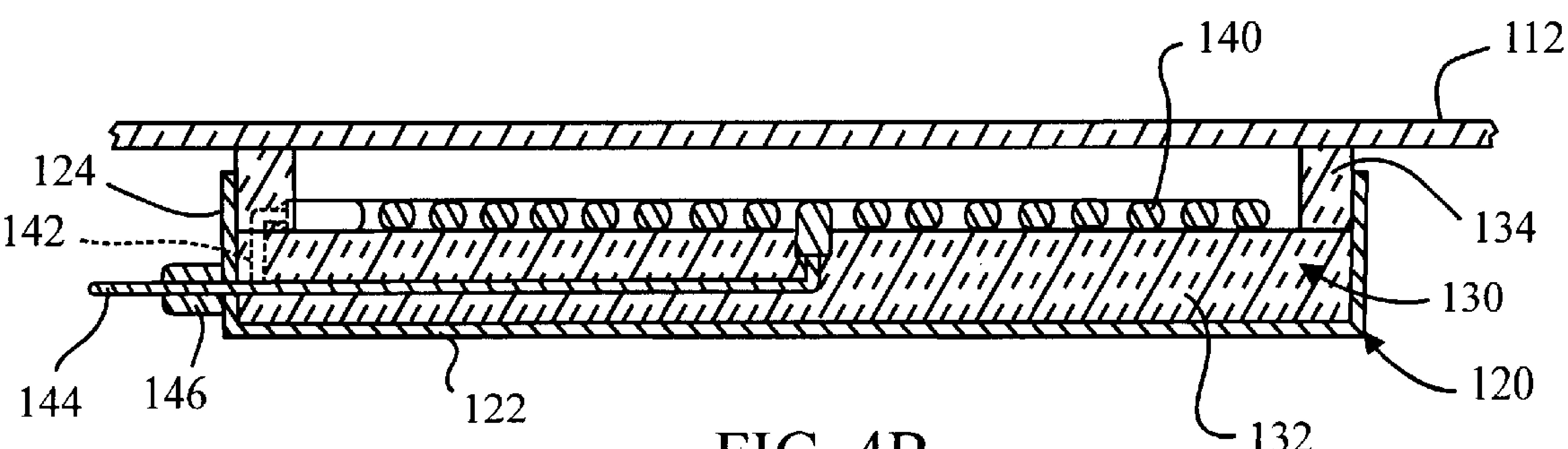

140
112
124
134
142
130
120
144
146
122
132

FIG. 4B

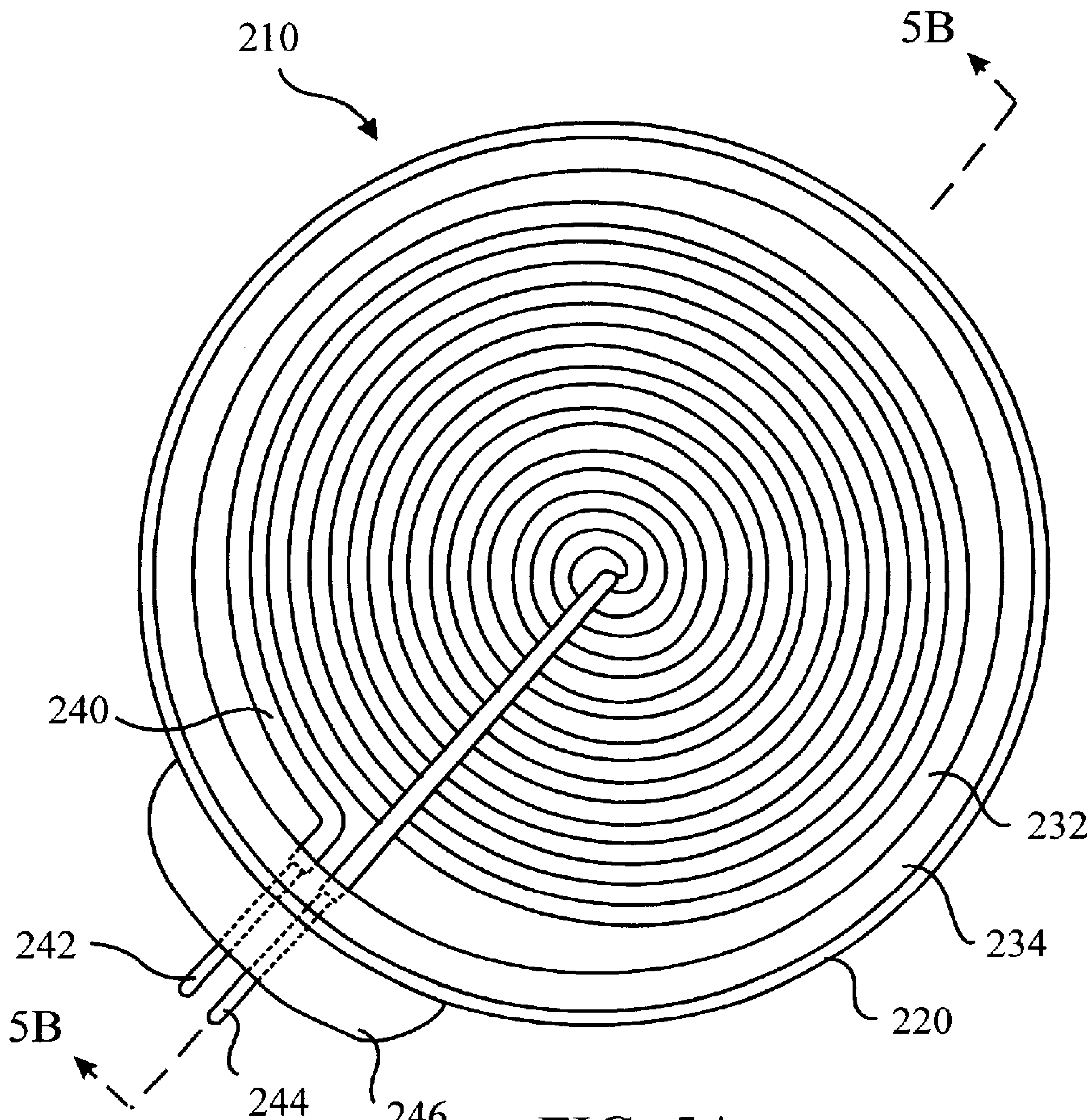

210
5B
240
232
242
234
220
5B
244
246

FIG. 5A

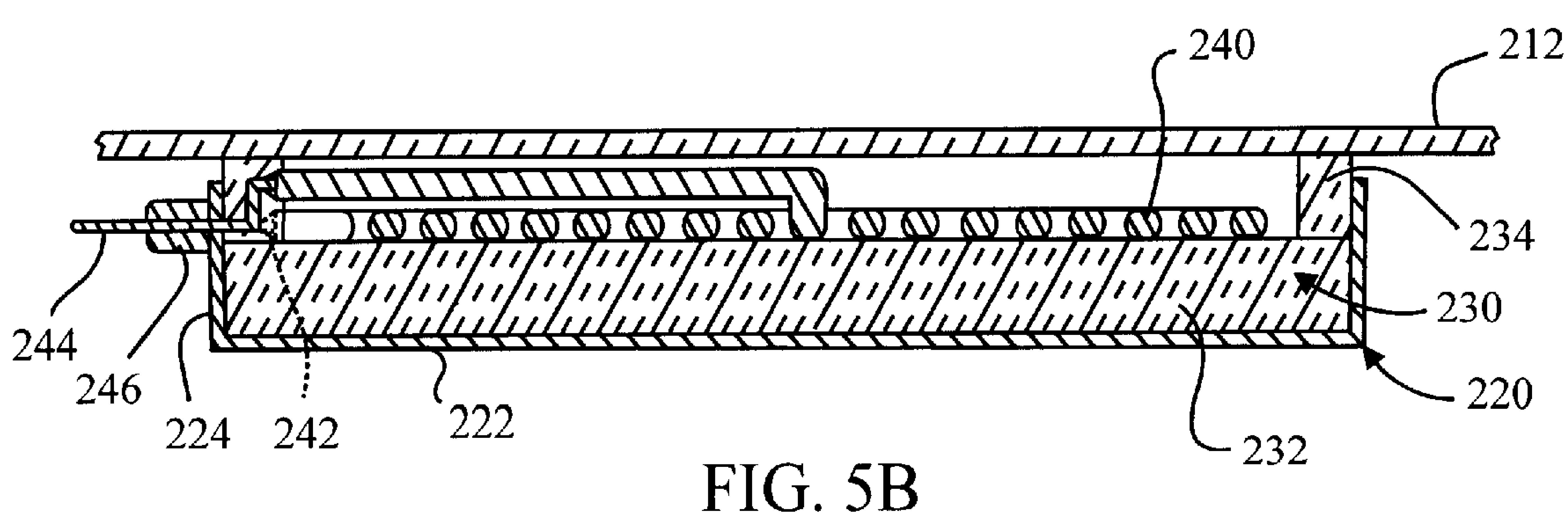

240
212
234
230
244
220
246
224
242
222
232

FIG. 5B

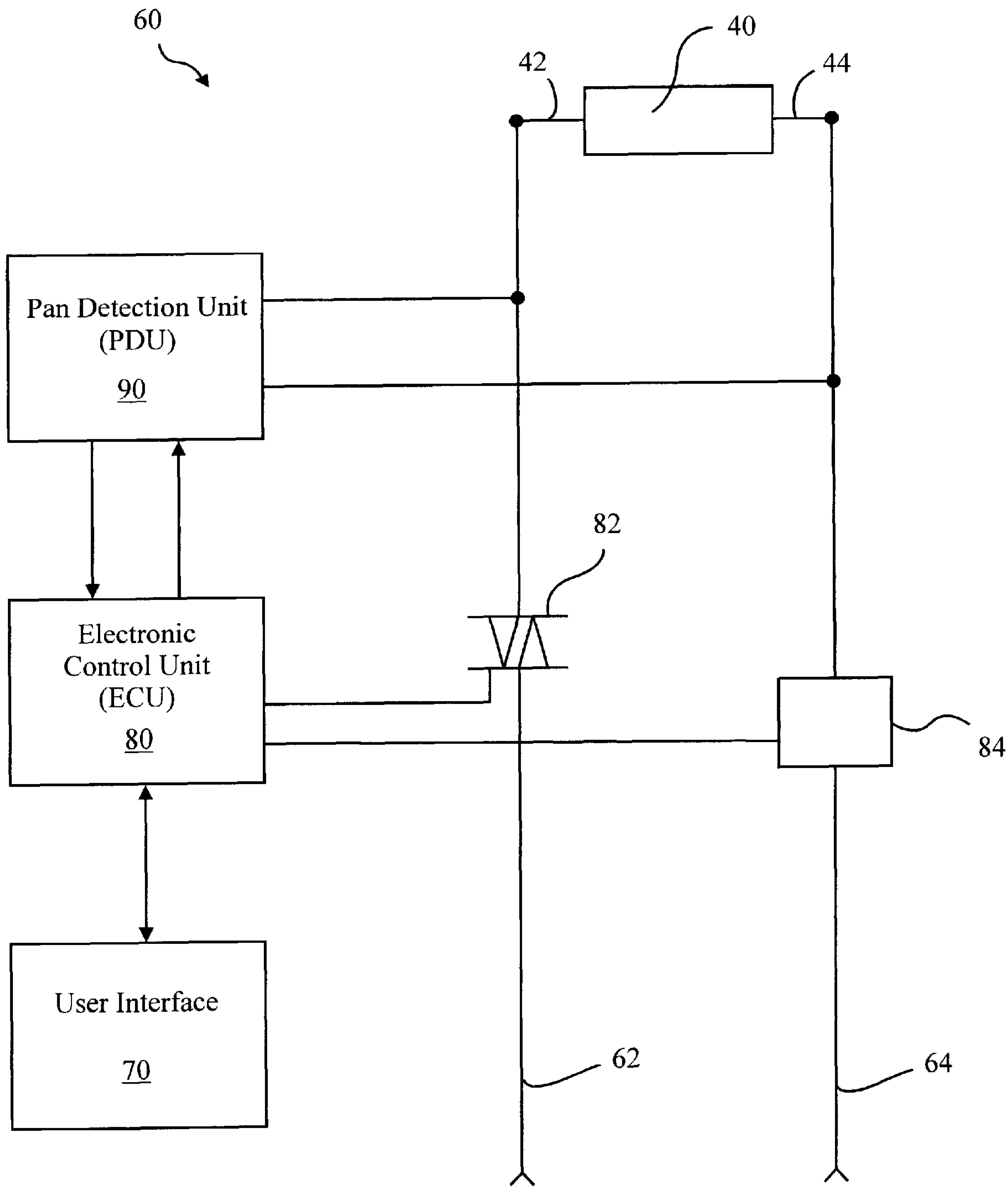

60
40
42
44
Pan Detection Unit
(PDU)
90
82
Electronic
Control Unit
(ECU)
80
84
User Interface
70
62
64

FIG. 6

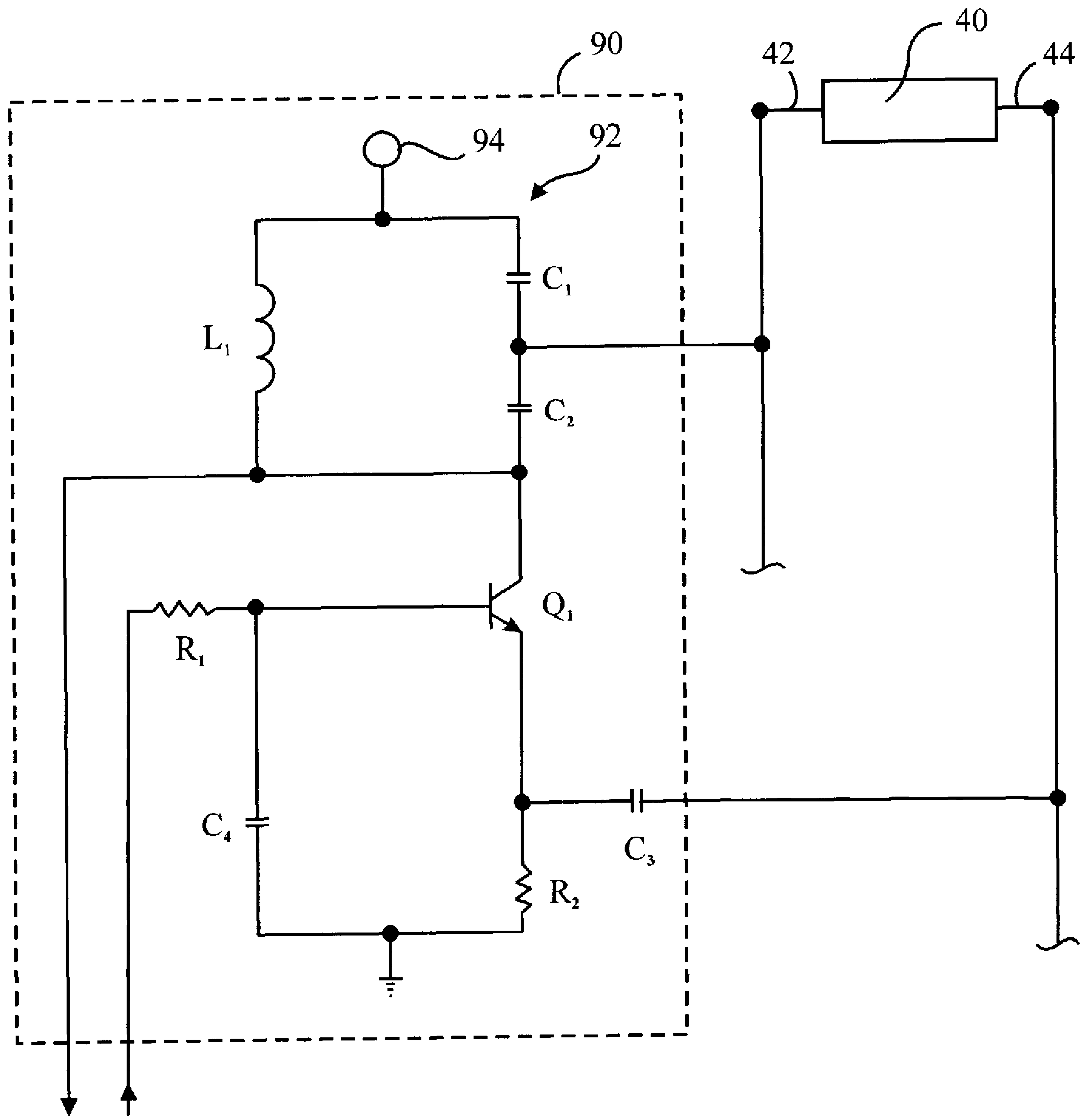


FIG. 7

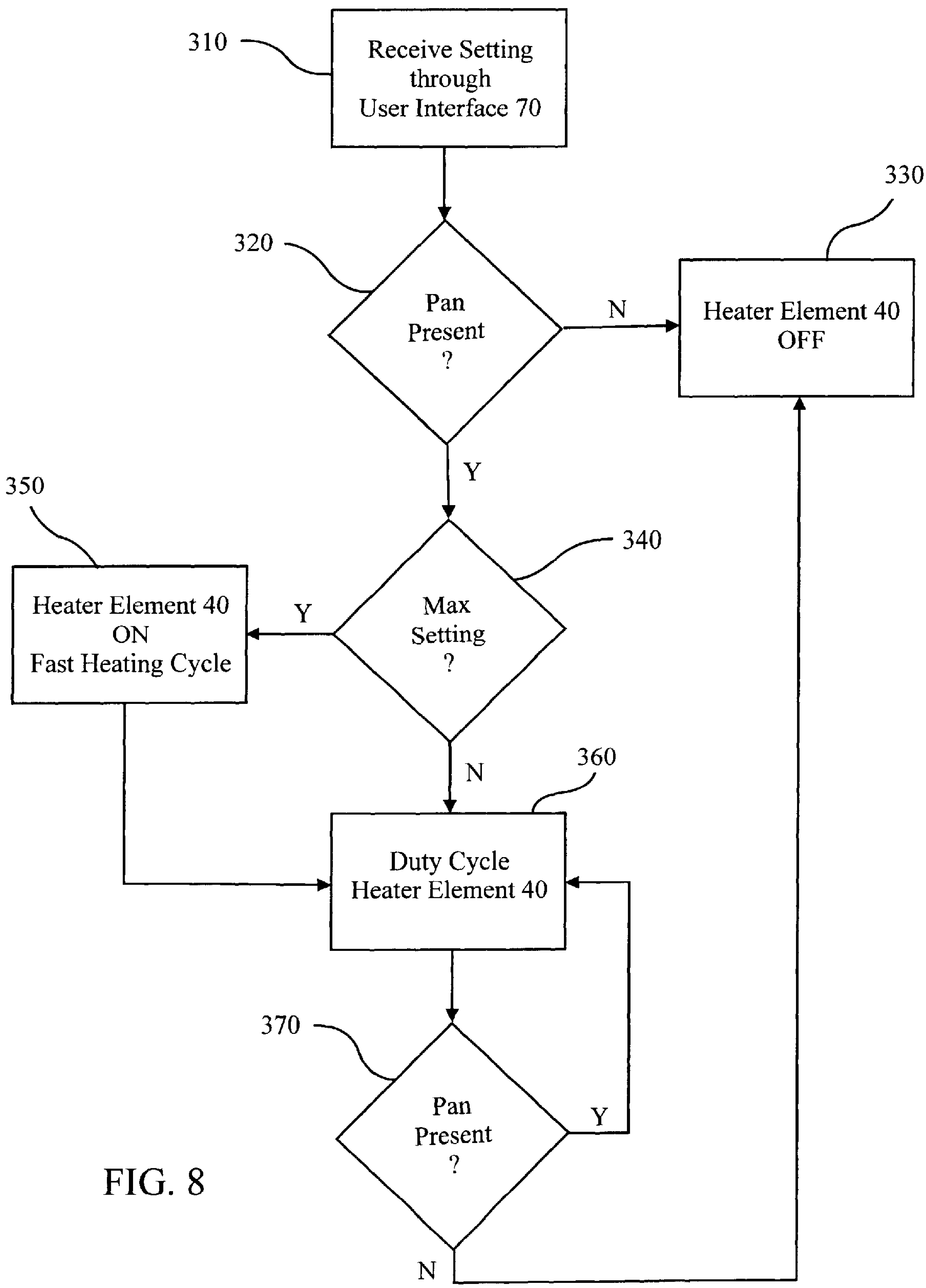

310
Receive Setting through User Interface 70
320
Pan Present ?
N
330
Heater Element 40 OFF
Y
350
340
Heater Element 40 ON Fast Heating Cycle
Y
Max Setting ?
N
360
Duty Cycle Heater Element 40
370
Pan Present ?
Y
N

FIG. 8

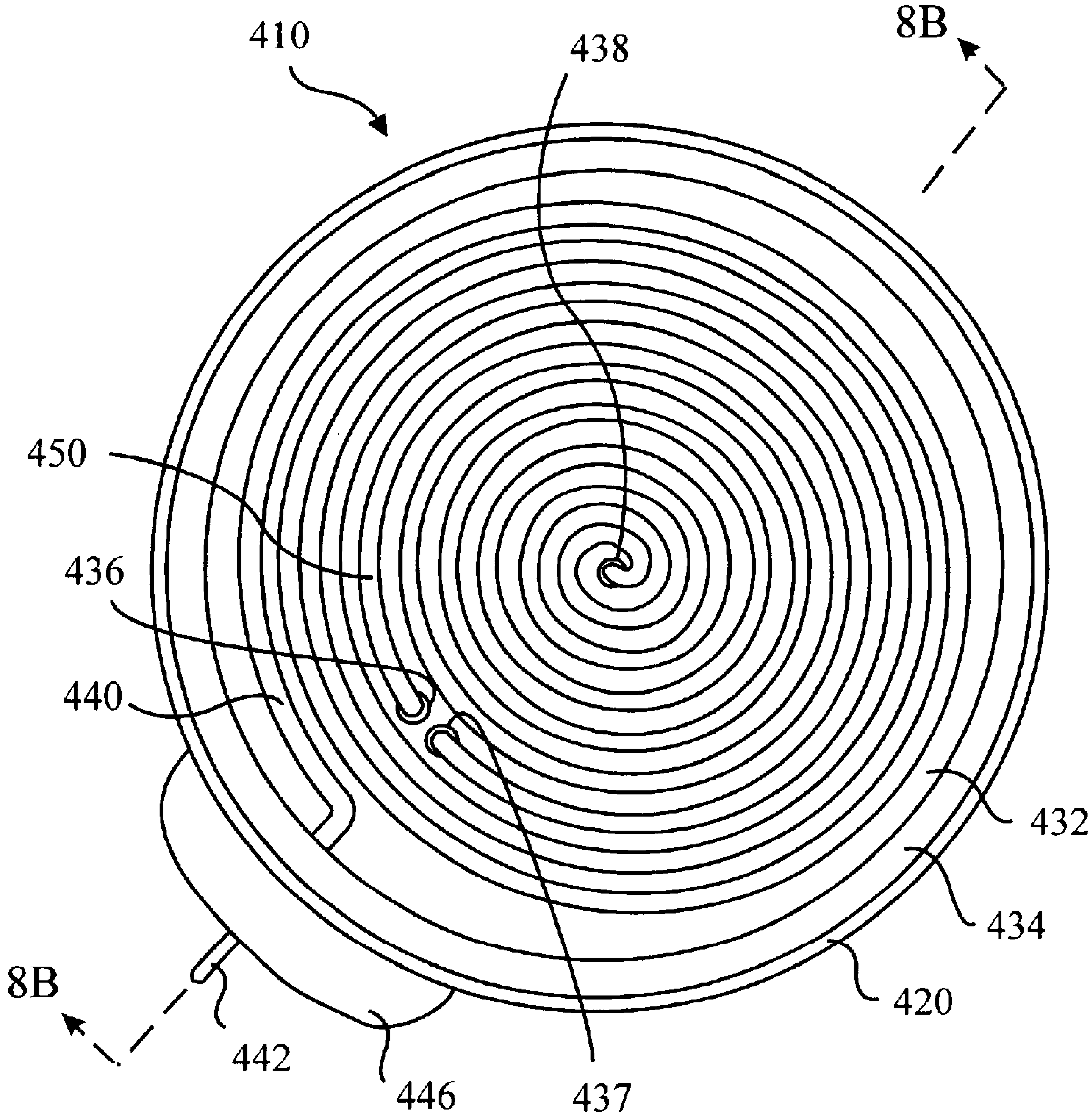

410
438
8B
450
436
440
432
434
420
8B
442
446
437

FIG. 9A

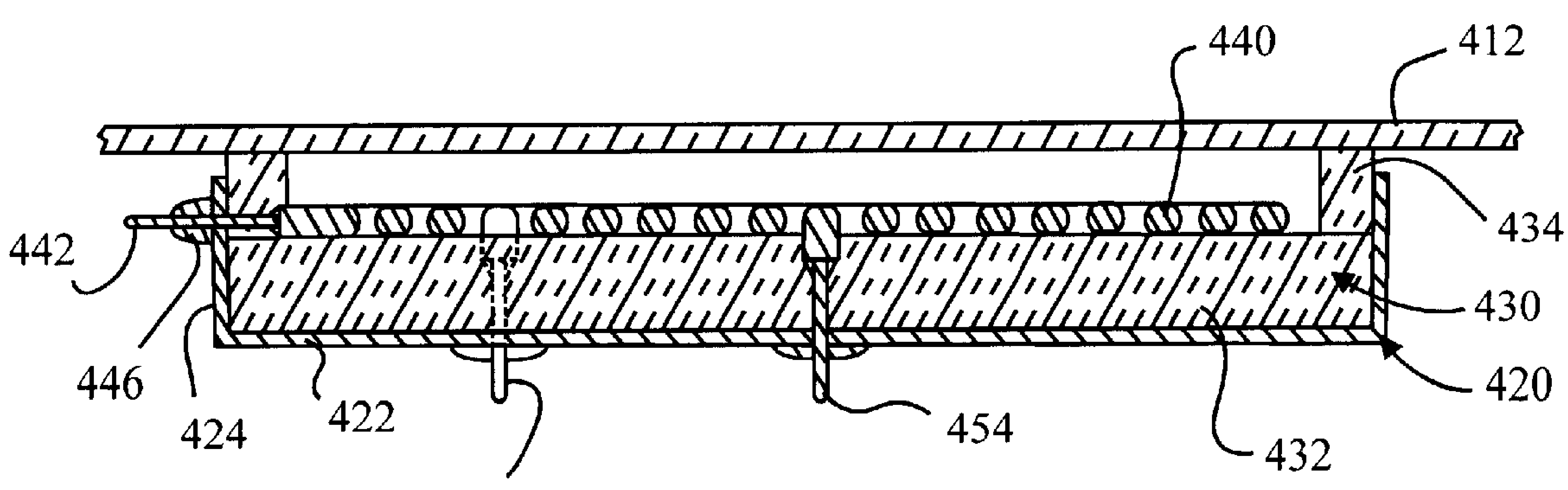

440
412
442
434
430
420
446
424
422
454
432
452

FIG. 9B

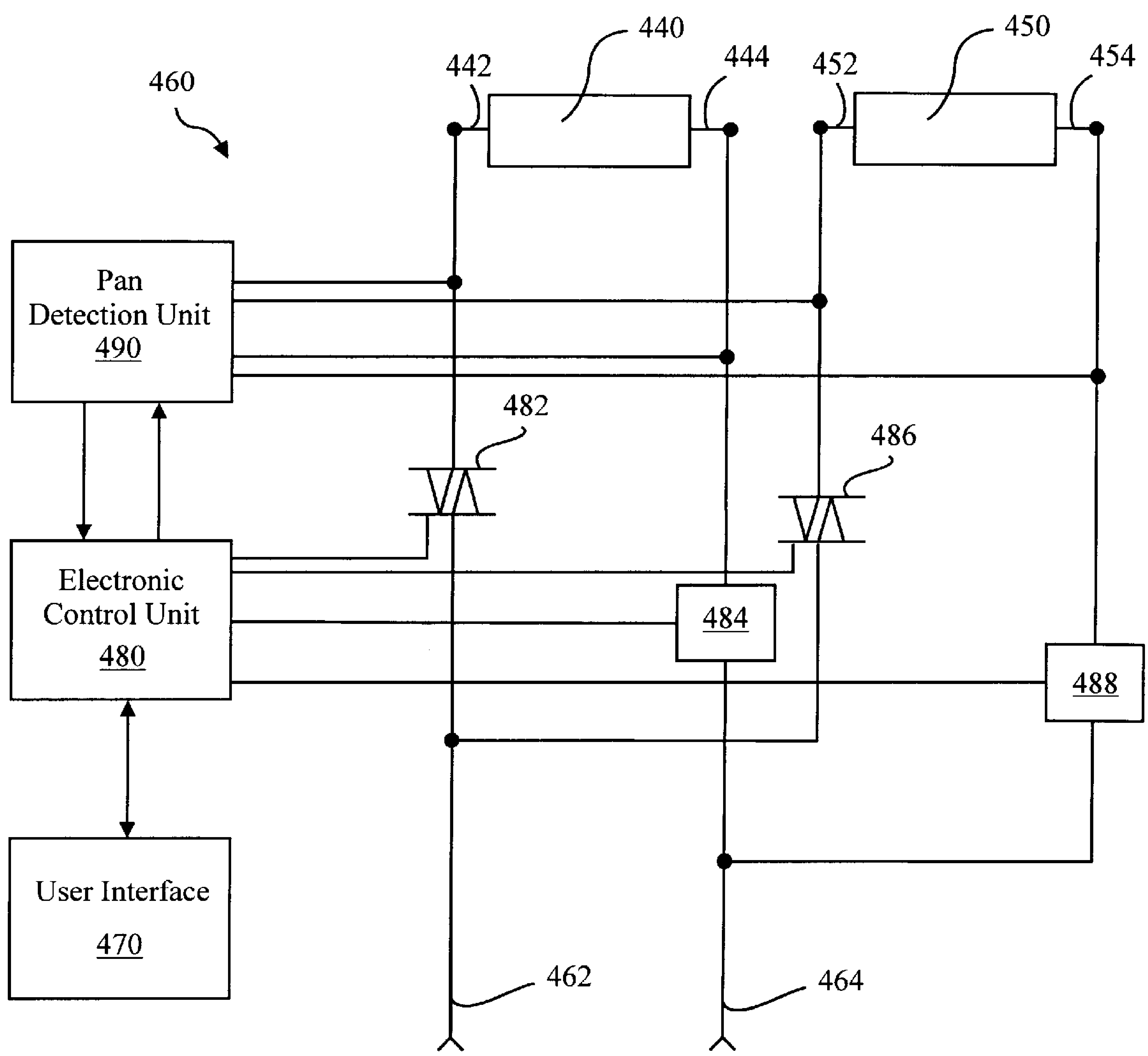

460
440
442
444
450
452
454
Pan
Detection Unit
490
482
486
Electronic
Control Unit
480
484
488
User Interface
470
462
464

FIG. 10

HEATING UNIT AND CONTROL SYSTEM FOR COOKTOPS HAVING CAPABILITY TO DETECT PRESENCE OF A PAN AND METHODS OF OPERATING SAME

FIELD OF THE INVENTION

The present invention relates generally to cooktop ranges, and more particularly, to radiant electric heating units and control systems for cooktop ranges having the capability of detecting the presence of a cooking pan or utensil and methods of operating the same.

BACKGROUND OF THE INVENTION

Several conventional cooktop ranges have a smooth glass-ceramic cooking surface. Mounted below the glass-ceramic cooking surface is one or more radiant electric heating units comprising typically of a coiled heater element. Power is supplied to the coiled heater element to heat a cooking pan or utensil placed on the glass-ceramic cooking surface. The glass-ceramic cooking surface is easier to clean than other types of cooktop ranges such as a gas range or a range that requires the pan to be placed directly on top of the heater element.

It has been known to detect the presence of a cooking pan or utensil on a cooktop range by using devices such as a weight sensor, a reed switch, or an optical sensor. These systems require extra components that may be subject to failure due to the high temperature environment of the heating unit.

Other previous attempts at pan detection involve placing coils around the outside of the heating element, embedding wires in the glass-ceramic cooking surface, or bonding wires to the bottom surface of the glass-ceramic cooking surface. More recently, there have been systems that deposit a gold foil pattern on the bottom surface of the glass-ceramic cooking surface. A current is sent through the wire or foil and any changes in the inductance is used by the control system of the cooktop to determine if a pan is present or absent. Each of these techniques requires expensive processing steps and requires materials that are capable of withstanding the high temperature environment. Moreover, replacement and maintenance of these systems may be difficult if the wire or foil fails.

The present invention is directed to overcoming, or at least reducing the effects of, one or more of the problems set forth above.

SUMMARY OF THE INVENTION

To that end, the present invention includes a control system for a heating unit in a cooktop that is capable of detecting the presence (or absence) of a cooking pan or utensil. The heating unit has a spirally wound ribbon heater element and may be mounted below a glass-ceramic cooking surface. The control system includes a pan detection unit electrically connected to the heater element. The pan detection unit generates a high frequency signal through the heater element to determine whether a pan is present on the cooktop. The pan detection unit may have an oscillation circuit to generate the high frequency signal through the heater element.

The control system may further include an electronic control unit that is electrically connected to the pan detection unit. The electronic control unit is capable of generating a signal to the pan detection unit to enable the pan detection unit to generate the high frequency signal through the heater element. In response, the pan detection unit is capable of sending a response signal to the electronic control unit that may reflect at least a portion of the reactance of the heater element. The electronic control unit may use this information to determine whether a pan is present. The control system may also include a user interface that is electrically connected to the electronic control unit.

The control system may further include at least one switch device. The at least one switch device is connected between the heater element and a power source. In one embodiment, the at least one switch device is opened when the pan detection unit generates the high frequency signal through the heater element.

In another embodiment, the present invention includes a control system for a heating unit in a cooktop that includes a pan detection unit, and at least one switch device. The heating unit has a heater element with a first terminal end and a second terminal end. The pan detection unit is electrically connected to the first and second terminal ends of the heater element. The pan detection unit is capable of generating a high frequency signal through the heater element to determine whether a pan is present on the cooktop. The at least one switch device is electrically connected between the heater element and a power source. The at least one switch device is opened to remove the power source from the heater element when the pan detection unit generates the high frequency signal through the heater element.

In a further embodiment, the present invention includes a control system for a heating unit with dual heater elements in a cooktop. In particular, the heating unit has an inner heater element and an outer heater element. The inner heater is spirally wound within the outer heater element. The control system includes a pan detection unit, a first switch device, and a second switch device. The pan detection unit is electrically connected to the inner and outer heater elements. The pan detection unit is capable of generating a high frequency signal through the inner heater element to determine whether a pan is present on the cooktop. The pan detection unit is also capable of generating a high frequency signal through the outer heater element to determine the size of the pan on the cooktop. The first switch device is electrically connected between the inner heater element and a power source. The first switch device is opened to remove the power source from the inner heater element when the pan detection unit generates the high frequency signal through the inner heater element in determining whether a pan is present on the cooktop. The second switch device is electrically connected between the outer heater element and the power source. The second switch device is opened to remove the power source from the outer heater element when the pan detection unit generates the high frequency signal through the outer heater in determining the size of the pan on the cooktop.

A further embodiment of the present invention includes a method of operating a heating unit for a cooktop with a control system that is capable of detecting whether a pan is present on the cooktop. The heating unit has a heater element and may be mounted below a glass-ceramic cooking surface. The method includes the steps of: receiving a setting from a user of the cooktop; generating a high frequency signal through the heater element; determining whether the pan is present on the cooktop from the generation of the high frequency signal through the heater element; isolating power to the heater element if it is determined that the pan is not present on the cooktop; providing power to the heater element if it is determined that the pan is present on the cooktop; determining whether the pan has been removed from the cooktop after power has been provided to the heater element; isolating power to the heater element if it is determined that the pan has been removed from the cooktop; and providing power to the heater element if it is determined that the pan has not been removed from the cooktop.

The step of generating the high frequency signal through the heater element may be performed by a pan detection unit having an oscillation circuit. The step of determining whether the pan is present on the cooktop may be performed by an electronic control unit that is electrically connected to the pan detection unit. The step of determining whether the pan has been removed from the cooktop may be performed by an electronic control unit that is electrically connected to the pan detection unit.

The above summary of the present invention is not intended to represent each embodiment, or every aspect of the present invention. This is the purpose of the figures and detailed description that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings.

FIG. **1** is a top view of a cooktop stove having four heating units of the present invention.

FIG. **2**A is a top view of one embodiment of a heating unit of the present invention.

FIG. **2**B is a cross-sectional view of the heating unit in FIG. **2**A.

FIG. **3**A is a side view of a portion of a heater element of the heating unit in FIG. **2**A showing the electromagnetic field that is created when a signal is applied to the heater element.

FIG. **3**B is a cross-sectional view of the heater element in FIG. **3**A.

FIG. **4**A is a top view of an alternative embodiment of a heating unit of the present invention.

FIG. **4**B is a cross-sectional view of the heating unit in FIG. **4**A.

FIG. **5**A is a top view of another alternative embodiment of a heating unit of the present invention.

FIG. **5**B is a cross-sectional view of the heating unit in FIG. **5**A.

FIG. **6** is a schematic view of one embodiment of a control system of the present invention.

FIG. **7** is a schematic of one embodiment of the pan detection unit of the control system shown in FIG. **6**.

FIG. **8** is a flow chart of one embodiment of a method of operating a heating unit according to the present invention.

FIG. **9**A is a top view of an alternative embodiment of a heating unit of the present invention having two separate heater elements.

FIG. **9**B is a cross-sectional view of the heating unit in FIG. **9**A.

FIG. **10** is an electrical schematic view of another embodiment of a pan detection system of the present invention for a heating unit having two separate heater elements.

While the invention is susceptible to various modifications and alternative forms, certain specific embodiments thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular forms described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Illustrative embodiments will now be described with reference to the accompanying figures. Turning to the drawings, FIG. **1** shows a plurality (four) of heating units **10** of the present invention installed below a cooking surface **12** in a cooktop **14**. The heating units **10** may each have the same wattage or the heating units **10** may have different wattages. Someone desiring to cook food or heat liquids places the food or liquid in a utensil (not shown) which is then set upon the cooking surface **12** above one of the heating units **10**. The user then turns the corresponding control knob **16** or other temperature control device to a setting indicating the temperature to be produced by the heating unit **10** to heat the food or liquid.

The cooking surface **12** may be a single sheet made of an infrared transmissive material such as glass-ceramic. A suitable material is designated as CERAN manufactured by Schott Glass in Mainz, Germany or EuroKera Glass Ceramic manufactured by EuroKera North America, Inc. in Fountain Inn, S.C. The use of such a glass-ceramic material maximizes the transmission of radiated heat from the heater element to a cooking pan or utensil that may rest on top of the cooking surface **12**.

As shown in FIGS. **2**A and **2**B, in one embodiment, the heating unit **10** includes a support pan **20**, an insulation layer **30**, and a heater element **40**. The support pan **20** is disposed beneath the cooking surface **12** and may be a shallow pan having a substantially flat base **22** and a circumferential sidewall **24**. The insulation layer **30** is supported inside the support pan **20**. Specifically, in one embodiment, as shown in FIG. **2**B, the insulation layer **30** has an insulation cake base **32** and an insulation sidewall ring **34**. Although FIG. **2**B shows the insulation layer **30** as two separate components, the insulation cake base **32** and the sidewall ring **34** may be a single unitary body. Suitable materials for the insulation layer include Wacker WDS® Thermal Insulation from Wacker Silicones Corp. in Adrian, Mich. and RPC2100 from Thermal Ceramics in Augusta, Ga.

The heater element **40** is supported on the insulation cake base **32** of the insulation layer **30**. The presence of the insulation sidewall ring **34** permits the heater element **40** to be in a spaced-apart relationship to the cooking surface **12**. The insulation sidewall ring **34** further assists in confining the heat to the area directly above the heater element **40** by minimizing the amount of heat loss to the sides of the heater unit **10**.

The heater element **40** is preferably an electric ribbon-type heater element. The heater element **40** radiates infrared energy. The heater element **40** has a first and second terminal end **42**, **44** that allows the heater element to be electrically connected to a control system **60** (see FIG. **6**) that supplies power through the heater element **40**. Conventional heater elements typically have a serpentine, sinuous or zigzag pattern. However, in the present invention, it is preferred that the heater element have a spirally wound pattern when installed on the insulation cake base **32**. In one embodiment, the first terminal end **42** of the heater element **40** is connected to the control system **60** via the terminal block **46**. The second terminal end **44** of the heater element **40** passes through a center hole **36** in the insulation cake base **32** to connect to the control system **60**.

It is now desirable to have a heating unit **10** with a control system **60** that is capable of detecting the presence (or absence) of a cooking pan or utensil. Detecting the presence of a cooking pan or utensil can provide safety and operational advantages to an electronically controlled cooktop **14**. As a safety improvement, the control system **60** can automatically disable power to the heater element **40** where a cooking pan or utensil has been removed. This would decrease the likelihood of an accidental burn to users of the cooktop **14**. The control system **60** can also disregard the user's request to turn on the cooktop **14** when no cooking pan or utensil is sensed on the cooking surface **12** of the cooktop **14**. As an operational improvement, the heating unit **10** could perform a fast heating cycle by applying more energy to the heater element **40** when the control system **60** senses the presence of a cooking pan or utensil.

To this end, the present invention includes a control system **60** that uses the electromagnetic effects of an electrically conductive cooking pan or utensil upon the electrical reactance of the spirally wound, electric ribbon-type heater element **40** to detect the presence (or absence) of the cooking pan or utensil. Referring to FIGS. **3**A and **3**B, the heater element **40** is excited by a radio frequency signal (in direction A) that produces an electromagnetic field **48**. The presence of a cooking pan or utensil (not shown) disrupts the electromagnetic field causing an apparent change in the reactance of the heater element **40**. The change of reactance can be measured at the first and second terminal ends **42, 44** of the heater element **40**.

In the present invention, as mentioned above, it is preferable that the heater element **40** be in a spirally wound pattern. Many conventional heating units have heater elements that are in a serpentine, sinuous or zigzag pattern. Such conventional patterns are relatively non-inductive due to the cancellation of the electromagnetic fields from alternating clock-wise and counter-clockwise portions of the pattern. This will not generate sufficient electromagnetic fields in the region of the pan and, thus, are typically not adequate to be used to detect the presence (or absence) of a cooking pan or utensil. The spirally wound pattern shown in FIG. 2A, however, eliminates the cancellation effects of the zigzag pattern and allows the generation of measurable electromagnetic fields in the region of the cooking pan or utensil.

Moreover, several conventional heating units have heater elements that are made of helical wound wires. A helical wound wire axially concentrates the magnetic fields to the interior of the helix. The exterior fields of a helical wound wire are generally confined to the space just outside the helix without generating fields in the region of a cooking pan or utensil. Accordingly, this typically makes a helical wound-type heater element unsuitable. A heater element made of a flat electrical ribbon, however, readily generates fields in the region of a cooking pan or utensil and, therefore, is useful in detecting the absence or presence of the cooking pan or utensil.

As explained in the background section, prior systems have used expensive processing steps to deposit gold or other materials to the glass-ceramic cooking surface of the cooktop. The present invention, however, uses the heater element **40** to sense the presence of a cooking pan or utensil. Using the heater element **40** eliminates the need to add expensive sensing devices that must withstand the high temperature environment.

The embodiment in FIGS. 2A and 2B shows the first and second terminal ends **42, 44** of the heater element **40** in different locations. This may not be suitable for all applications because it does not permit immediate access to both terminal ends **42, 44** in a single terminal block at the outer edge of the heating unit **10**. In some applications, the terminal ends of a heater element may need to be located in a single terminal block at the outer edge of the heating unit. Accordingly, FIGS. **4**A, **4**B and **5**A, **5**B show alternative embodiments of a heating unit according to the present invention that allows access to both terminal ends in a single terminal block at the outer edge of the heating unit.

In FIGS. **4**A and **4**B, a heating unit **110** includes a support pan **120**, an insulation layer **130**, and a heater element **140**. The support pan **120** is disposed beneath the cooking surface **12** and may comprise a substantially flat base **122** and a circumferential sidewall **124**. The insulation layer **130** is supported inside the support pan **120**. The insulation layer **130** may have an insulation cake base **132** and an insulation sidewall ring **134**. The heater element **140** is supported on the insulation cake base **132** and is preferably a ribbon-type heater element that is spirally wound. In this embodiment, the heater element **140** has a first and second terminal end **142, 144** that allows the heater element to be electrically connected to the control system **60** (see FIG. **6**). The terminal ends **142, 144** of the heater element **140** are connected to the control system **60** via the terminal block **146**. The second terminal end **144** passes through the center of the insulation cake **132** and is then routed to the outer edge of the heating unit **110** through the insulation cake **132**.

In FIGS. **5**A and **5**B, a heating unit **210** includes a support pan **220**, an insulation layer **230**, and a heater element **240**. The support pan **220** is disposed beneath the cooking surface **12** and may comprise a substantially flat base **222** and a circumferential sidewall **224**. The insulation layer **230** is supported inside the support pan **220**. The insulation layer **230** may have an insulation cake base **232** and an insulation sidewall ring **234**. The heater element **240** is supported on the insulation cake base **232** of the insulation layer **230** and is preferably a ribbon-type heater element that is spirally wound. In this embodiment, the heater element **240** has two terminal ends **242, 244** that allow the heater element to be electrically connected to the control system **60** (see FIG. **6**). The terminal ends **242, 244** of the heater element **240** are connected to the control system **60** via the terminal block **246**. The second terminal end **244** is routed from the center of the heating unit **210** to the outer edge of the heating unit **210** by passing the second terminal end **244** over the heater element **240**.

Referring to FIG. **6**, one embodiment of a control system **60** for the present invention includes a user interface **70**, an electronic control unit **80**, switch devices **82, 84**, and a pan detection unit **90**. As explained above, the heater element **40** is preferably a spirally wound, ribbon-type heater element. The heater element **40** has a first and second terminal end **42, 44**. The terminal ends **42, 44** of the heater element **40** are connected to AC power lines **62, 64** through switch devices **82, 84** to supply a voltage, for example, **240** VAC. The switch devices **82, 84** are controlled by the electronic control unit **80**. The switching devices **82, 84** supply AC power to the heater element when closed. As described in more detail below, the switching devices are also used to remove power to the heater element **40** when at least one of the switching devices are open. The switch devices **82, 84** may be relays, triacs, SCRs, or other types of electronically controlled switches. In one embodiment, the switch device **82** for the line associated with the first terminal end **42** is a triac and the switch device **84** for the line associated with the second terminal end **44** is a relay. The switch device **84** for the line associated with the second terminal end **44** acts as a safety device that disables during fault conditions or during extended periods of inoperation. The switch device **82** for the line associated with the first terminal end **42** turns the heater element **40** on and off according to the amount of heat required at any given instant in time. A triac is a suitable switch device **82** for this type of application because it is a fast acting switching device. A standard relay is typically too slow. As will be described later, in one embodiment, at least the faster acting switch (switch device **82**) is disabled during the time period when the reactance of the heater element **40** is being measured.

The user interface **70** may be a simple input knob **16** (see FIG. **1**), or a touch or wireless keyboard with advanced optical indicating devices. If an input knob **16** were used, the knob **16** would have a plurality of settings. For example, the knob **16** may have settings **1–10** where setting **1** refers to minimum heat and setting **10** refers to maximum heat. A user places a cooking pan or utensil on the cooking surface **12** above a heating unit **10** and turns the control knob **16** to a desired setting. For boiling liquids, a user will typically select the highest setting. The electronic control unit **80** will receive the desired setting from the knob **16**.

The electronic control unit **80** acts as the master controller of the system. The electronic control unit **80** receives a desired setting from the user through the user interface **70**. The electronic control unit **80** controls the application of power to the heater element **40** by activating the switch device **82** to achieve the desired setting. The electronic control unit **80** may also shut down the heater element **40** during a fault by disconnecting power through the switch device **84**. In one embodiment, a temperature sensor (not shown) may be used to determine whether a desired setting has been reached. In such a case, the electronic control unit **80** assigns a temperature set point according to the desired setting selected by the user of the cooktop **14**. The electronic control unit **80** turns on the power to the heater element **40** (through switch device **82**) until the temperature set point is reached. After the first temperature set point has been reached, the temperature is maintained by duty cycling the power supplied to the heater element **40**. The operation of the electronic control unit **80** may be accomplished by a PID (Proportional, Integral, Derivative) control loop or a PI (Proportional, Integral) control loop.

The electronic control unit **80** is also electrically connected to the pan detection unit **90** to determine the presence (or absence) of a cooking pan or utensil on the cooking surface **12** above a heating unit **10**. The pan detection unit **90** consists of circuitry that indicates the reactance of the heater element **40**. The pan detection unit **90** is electrically connected between the terminal ends **42**, **44** and the switch devices **82**, **84** to provide a radio frequency signal to the heater element **40**. The signal is generated such that any changes in the reactance of the heater element **40** will affect at least one parameter of the signal, i.e. amplitude, phase, time delay, frequency, or other characteristic.

In this embodiment, the electronic control unit **80** sends control signals to the pan detection unit **90** indicating when the radio frequency signal is to be enabled, and when the reactance of the heater element **40** is to be measured. The pan detection unit **90** responds with sensing signals indicative of the reactance magnitude of the heater element **40**. The electronic control unit **80** uses the received reactance magnitude from the pan detection unit **90** to determine whether a pan is present on the cooking surface **12**. Alternatively, the pan detection unit **90** may respond with an on-off indication of the presence of a cooking pan or utensil.

FIG. **7** illustrates one embodiment of a pan detection unit **90**. It has been discovered that monitoring differences in reactance or inductance can determine whether a pan is present on top of the cooking surface **12**. Accordingly, in one embodiment, the pan detection unit **90** indicates the reactance of the heater element **40** through the generation of a high-frequency current by an oscillation circuit **92**. In one embodiment, as shown in FIG. **7**, the oscillation circuit **92** is a Colpitts oscillator. One of ordinary skill in the art, however, having the benefit of the present specification would realize that other types of oscillation circuits may be used such as a Hartley, phase lock loop, or numerous other oscillators.

The oscillation frequency of the Colpitts oscillator in FIG. **7** is determined by the inductor **L1**, capacitors **C1**, **C2**, **C3**, and the heater element **40**. Typically, a frequency that can provide an optimum oscillation is selected from among frequencies of 100 KHz to 10 MHz, although other frequencies could be used. The pan detection unit **90** further includes a resistance **R2** connected to the emitter of the transistor **Q1** for varying the conditions of oscillation. As the resistance value of the resistance **R2** is varied, the oscillation amplitude value varies. In one embodiment, a source voltage **94** for the oscillation circuit **92** was set at +5V, although one of ordinary skill in the art would realize that other voltages may be used.

To begin the process of determining whether a cooking pan or utensil is present (or absent) from the cooking surface **12**, in one embodiment, the electronic control unit **80** opens at least the faster switch device (here, switch device **82**) to remove power supplied to the heater element **40**. It was found that the external AC power lines **62**, **64** present an unknown impedance at the radio frequencies typically used in detecting the presence of a cooking pan or utensil. Any variations would directly affect the reliability of measuring the reactance of the heater element **40**. Alternatively, the external AC power lines **62**, **64** could be reduced by a line impedance stabilization network (not shown). This is a specially designed filter that prevents the radio frequency signals from reaching the power lines. The filter would have to be heavy enough to carry the full heating power of the heater element **40**. To be effective, such a filter may be unreasonably large and expensive. Accordingly, the preferred method is isolating the heater element **40** from the external AC power lines **62**, **64** through opening at least the faster switch device **82**.

After power is removed to the heater element **40**, the electronic control unit **80** may send a control signal to the pan detection unit **90** (and oscillation circuit **92**) through the line having resistance **R1**. As explained above, the oscillation circuit **92** then generates a high-frequency current through heater element **40**. Any change of reactance in the heater element **40** will cause a subsequent change in the oscillator's frequency. In one embodiment, the electronic control unit **80** has a frequency counting circuit. The pulse signal from the collector of the transistor **Q1** can be used by a frequency counting circuit in the electronic control unit **80** as an indication of the reactance of the heater element **40**.

One requirement of heating units is that they now be able to rapidly heat up to an operating temperature. This is evidenced by a heater element **40** of the heating unit **10** reaching a visual response temperature within 3–5 seconds after application of power, by which time the heater element **40** is glowing. Rapid heating of element **40** may be achieved by applying a voltage, for example, 240 VAC across the heater element **40**. The voltage is applied the entire time the heater element **40** is on. While this achieves rapid heating, the tradeoff has been increased temperature stress on the heater element **40** and cooking surface **12**. This may result in reduced service life of the cooking surface **12**. Thus, it is desirable to have a control system that minimizes the temperature stresses on the cooking surface **12**. Accordingly, in one operational mode of the present invention, the electronic control unit **80** determines whether a cooking pan or utensil is present (or absent) on the cooking surface **12** above a heating unit **10**. As explained above, this is done with the use of the pan detection unit **90**. If a cooking pan or utensil is present, the electronic control unit **80** can then perform a fast heating cycle by closing the switch device **82** without duty cycling. When the desired temperature has been reached, the electronic control unit **80** may then duty cycle. If no pan is present, the electronic control unit **80** may not turn on the heater element **40** or it may perform a slow heating cycle by duty cycling the switch device **82** until the desired temperature is reached.

The present invention also includes a method of operating a heating unit **10** with a control system **60** that senses the presence (or absence) of a cooking pan or utensil. Referring to the block diagram in FIG. **8**, in Block **310**, the control system **60** receives a temperature setting through the user interface **70**. As explained above, the temperature setting may be received through a simple input knob **16** (see FIG. **1**), or a touch or wireless keyboard with advanced optical indicating devices. If an input knob **16** were used, the knob **16** may have a plurality of settings. For example, the knob **16** may have settings **1–10** where setting **1** refers to minimum heat and setting **10** refers to maximum heat.

In block **320**, the control system **60** determines whether a cooking pan or utensil is present on the cooking surface **12** above the heating unit **10**. As explained above, in one embodiment, the electronic control unit **80** removes power to the heater elements **40** by opening at least one of the switch devices **82, 84**. This should preferably be a faster acting switch such as a triac. The electronic control unit **80** then sends a control signal to the pan detection unit **90** indicating that a radio frequency signal should be generated and sent through the heater element **40**. The pan detection unit **90** responds with sensing signals indicative of the reactance magnitude of the heater element **40**. The electronic control unit **80** uses the received reactance magnitude from the pan detection unit **90** to determine whether a cooking pan or utensil is present on the cooking surface **12**. If a cooking pan or utensil is not present, the control system **60** may keep the heater element **40** off (see block **330**). Otherwise, if a cooking pan or utensil is present, the control system **60** may go on to block **340**.

In block **340**, the control system **60** may then determine whether the setting received in block **310** refers to maximum heat. If the setting refers to maximum heat, the control system **60** then turns the heater element **40** on a fast heating cycle. For example, to boil liquids, a user will typically select maximum heat. The electronic control unit **80** may do this. As explained above, rapid heating of the heater element **40** may put increased temperature stress on the cooking surface **12**. This is especially true when no cooking pan or utensil is present on the cooking surface **12**. When a cooking pan or utensil is present on the cooking surface **12**, the cooking pan or utensil may act as a heat sink that reduces the amount of temperature stress on the cooking surface **12**. Accordingly, before entering a fast heating cycle (block **350**) it may be important to know whether a cooking pan or utensil is present on the cooking surface **12**. If the setting does not refer to maximum heat, there are a variety of ways known to those of ordinary skill in the art to turn on the heater element **40** to achieve the desired setting. In one embodiment, the heater element **40** is turned on and after the desired temperature setting has been reached the setting is maintained by duty cycling the power supplied to the heater element **40** (block **360**).

Between duty cycling the power supplied to the heater element **40**, the control system **60** may continue to check whether the cooking pan or utensil is still present on the cooking surface **12** (block **370**). The same procedure as described above in relation to block **360** may be used. Namely, in one embodiment, the electronic control unit **80** removes the AC power from the heater element **40** by opening at least switch device **82**. The electronic control unit **80** then sends a control signal to the pan detection unit **90** indicating that a radio frequency signal should be generated and sent through the heater element **40**. The pan detection unit **90** responds with sensing signals indicative of the reactance magnitude of the heater element **40**. The electronic control unit **80** uses the received reactance magnitude from the pan detection unit **90** to determine whether a cooking pan or utensil is present on the cooking surface **12**. If a cooking pan or utensil is still present, the control system **60** continues to maintain the setting by continuing to duty cycle the power supplied to the heater element **40** (see block **360**). Otherwise, if the cooking pan or utensil has been removed, the control system **60** may go on to block **330** and turn off the heater element **40**.

In another embodiment, the present invention includes a heating unit having two or more heater elements. Referring to FIGS. **9A** and **9B**, in one embodiment, a heating unit **410** includes a support pan **420**, an insulation layer **430**, an outer heater element **440**, and an inner heater element **450**. The support pan **420** is disposed beneath the cooking surface **12** and may be a shallow pan having a substantially flat base **422** and a circumferential sidewall **424**. The insulation layer **430** is supported inside the support pan **420**. Specifically, in one embodiment, as shown in FIG. **9B**, the insulation layer **430** has an insulation cake base **432** and an insulation sidewall ring **434**. Although FIG. **9B** shows the insulation layer **430** as two separate components, the insulation cake base **432** and the sidewall ring **434** may be a single unitary body. Similar to the previous embodiments, suitable materials for the insulation layer include Wacker WDS® Thermal Insulation from Wacker Silicones Corp. in Adrian, Mich. and RPC2100 from Thermal Ceramics in Augusta, Ga.

The heater elements **440, 450** are supported on the insulation cake base **432** of the insulation layer **430**. The presence of the insulation sidewall ring **434** permits the heater elements **440, 450** to be in a spaced-apart relationship to the cooking surface **12**. The insulation sidewall ring **434** further assists in confining the heat to the area directly above the heater elements **440, 450** by minimizing the amount of heat loss to the sides of the heater unit **410**.

The heater elements **440, 450** are preferably electric ribbon-type heater elements. The heater elements **440, 450** radiate infrared energy. The outer heater element **440** has terminal ends **442, 444** and the inner heater element **450** has terminal ends **452, 454**. (Note: The terminal end **444** is not specifically shown in FIG. **9B**. Terminal **444**, however, extends downward through hole **437** similar to terminal end **452**). The terminal ends allow the heater elements **440, 450** to be electrically connected to a control system **460** (see FIG. **10**). The control system **460** enables power to be supplied through the heater elements **440, 450**. Conventional heater elements typically have a serpentine, sinuous or zigzag pattern. However, in the present invention, it is preferred that the heater elements have a spirally wound pattern when installed on the insulation cake base **432**. Accordingly, the embodiment illustrated in FIG. **9**A shows the inner heater element **450** spirally wound within the outer heater element **440**. The purpose of dual heater elements is to conserve energy and to preserve the life of the cooking surface **12**. Depending on the size of the cooking pan or utensil, the control system **460** will turn on both heater elements **440, 450** (for a large cooking pan or utensil) or simply turn on the inner heater element **450** (for a small cooking pan or utensil).

In one embodiment, the first terminal end **442** of the outer heater element **440** is connected to the control system **460** via the terminal block **446**. The second terminal end **444** of the outer heater element **440** passes through a hole **437** in the insulation cake base **432** to connect to the control system **460**. The first terminal end **452** of the inner heater element **450** passes through a hole **436** in the insulation cake base **432** to connect to the control system **460**. The second terminal end **454** of the inner heater element **450** passes through a center hole **438** in the insulation cake base **432** to connect to the control system **460**.

Similar to the previously described embodiments, the control system **460** uses the electromagnetic effects of an electrically conductive cooking pan or utensil upon the electrical reactance of the spirally wound, electric ribbon-type heater elements **440, 450** to detect the presence (or absence) of the cooking pan or utensil. Each heater element **440, 450** is excited by a radio frequency signal that produces an electromagnetic field. The presence of a cooking pan or utensil (not shown) disrupts the electromagnetic field causing an apparent change in the reactance of each heater element **440, 450**. The change of reactance can be measured at the terminal ends of the heater elements **440, 450**. Depending on the reactance for each heater element **440, 450**, the control system **460** can further determine whether a large or small cooking pan or utensil has been placed on the cooking surface **12** above the heating unit **410**. Based on this information, the control system **460** may decide whether to activate one or both of the heater elements **440, 450**.

The control system **460** for heating unit **410** is similar to the one described above for the previous embodiments. Referring to FIG. **10**, one embodiment of the control system **460** includes a user interface **470**, an electronic control unit **480**, switch devices **482, 484, 486, 488** and a pan detection unit **490**. As explained above, the heater elements **440, 450** are preferably a spirally wound, ribbon-type heater element. The outer heater element **440** has terminal end **442, 444**. The terminal ends **442, 444** of the outer heater element **440** are connected to AC power lines **462, 464** through switch devices **482, 484** to supply a voltage, for example, 240 VAC. The inner heater element **450** has terminal end **452, 454**. The terminal ends **452, 454** of the inner heater element **450** are connected to AC power lines **462, 464** through switch devices **486, 488**.

The switch devices **482, 484, 486, 488** are controlled by the electronic control unit **480**. The switch devices **482, 484, 486, 488** may be relays, triacs, SCRs, or other types of electronically controlled switches. In one embodiment, the switch devices **482, 486** for the line associated with the first terminal ends **442, 452** of the heater elements are triacs. The switch devices **484, 488** for the line associated with the second terminal ends **444, 454** are relays. The switch devices **484, 488** for the line associated with the second terminal ends **444, 454** act as safety devices that disable during fault conditions or during extended periods of inoperation. The switch devices **482, 486** for the line associated with the first terminal ends **442, 452** turn the heater elements **440, 450** on and off according to the amount of heat required at any given instant in time. Triacs are suitable switch devices **482, 486** for this type of application because they are fast acting switching devices. Additionally, the switch devices **482, 486** associated with a particular heater element **440, 450** are disabled during the time period when the reactance of one of the heater elements **440, 450** are being measured.

The user interface **470** may be a simple input knob **16** (see FIG. **1**), or a touch or wireless keyboard with advanced optical indicating devices. If an input knob **16** were used, the knob **16** would have a plurality of settings. For example, the knob **16** may have settings **1–10** where setting **1** refers to minimum heat and setting **10** refers to maximum heat. A user places a cooking pan or utensil on the cooking surface **12** above a heating unit **10** and turns the control knob **16** to a desired setting. For boiling liquids, a user will typically select the highest setting. The electronic control unit **480** will receive the desired setting from the knob **16**.

The electronic control unit **480** acts as the master controller of the system. The electronic control unit **480** receives a desired setting from the user through the user interface **470**. The electronic control unit **480** controls the application of power to the heater elements **440, 450** by activating the switch devices **482, 486** to achieve the desired setting. The electronic control unit **480** may also shut down either heater element **440, 450** during a fault by disconnecting power through the switch devices **484, 488**. In one embodiment, a temperature sensor (not shown) may be used to determine whether a desired setting has been reached. In such a case, the electronic control unit **480** assigns a temperature set point according to the desired setting selected by the user of the cooktop **14**. The electronic control unit **480** turns on the power to one or both heater elements **440, 450** (through switch devices **482, 486**) until the temperature set point is reached. After the first temperature set point has been reached, the temperature is maintained by duty cycling the power supplied to the heater elements **440, 450**. The operation of the electronic control unit **480** may be accomplished by a PID (Proportional, Integral, Derivative) control loop or a PI (Proportional, Integral) control loop.

The electronic control unit **480** is also electrically connected to the pan detection unit **490** to determine the presence (or absence) of cooking pan or utensil on the cooking surface **12** above a heating unit **410**. In this embodiment, the electronic control unit **480** may also determine (through the pan detection unit **490**) whether a small or large cooking pan or utensil has been placed on the cooking surface **12** above a heating unit **410**. The pan detection unit **490** may consist of circuitry that is similar to the circuitry above described in relation to FIG. **7**. In one embodiment, the pan detection unit **490** has a separate oscillating circuit for each heater element **440, 450**. Alternatively, the pan detection unit **490** has a single oscillating circuit for each heater element **440, 450** but has relays or other switches to send a signal to each heater element **440, 450**. The circuitry of the pan detection unit **490** indicates the reactance of the heater elements **440, 450**. The pan detection unit **490** is electrically connected between the terminal ends of the heater elements **440, 450** and the switch devices **482, 484, 486, 488** to provide a radio frequency signal to each heater element **440, 450**. The signal is generated such that any changes in the reactance of either heater element **440, 450** will affect at least one parameter of the signal, i.e. amplitude, phase, time delay, frequency, or other characteristic.

In this embodiment, the electronic control unit **480** sends control signals to the pan detection unit **490** indicating when the radio frequency signal is to be enabled, and when the reactance of either heater element **440**, **450** is to be measured. The pan detection unit **490** responds with sensing signals indicative of the reactance magnitude of for each heater element **440**, **450**. The electronic control unit **480** uses the received reactance magnitude from the pan detection unit **490** to determine whether a pan is present on the cooking surface **12**. The electronic control unit **480** also uses the received reactance magnitude from the pan detection unit **490** to determine whether a small or large pan is present on the cooking surface **12**. Alternatively, the pan detection unit **490** may respond with an indication of the presence of a cooking pan or utensil or an indication on the size of the cooking pan or utensil.

What has been described is radiant heating units for use in cooktops that are capable of determining the presence of a cooking pan or utensil. The heating unit has a simple construction so the cooktop requires fewer parts than cooktops using conventional pan detection methods. This not only reduces costs, but also maintenance time.

In view of the foregoing, it will be seen that the several objects of the invention are achieved and other advantageous results are obtained.

As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A control system for a heating unit in a cooktop, the heating unit having a spirally wound ribbon heater element, the control system comprising a pan detection unit electrically connected to the heater element, wherein the pan detection unit is capable of generating a high frequency signal through the heater element to determine whether a pan is present on the cooktop.

2. The control system of claim **1**, wherein the cooktop has a glass-ceramic cooking surface, the heating unit and heater element mounted below the glass-ceramic cooking surface.

3. The control system of claim **1**, wherein the pan detection unit has an oscillation circuit to generate the high frequency signal through the heater element.

4. The control system of claim **1**, wherein the control system further includes an electronic control unit that is electrically connected to the pan detection unit, the electronic control unit capable of generating a signal to the pan detection unit to enable the pan detection unit to generate the high frequency signal through the heater element.

5. The control system of claim **4**, wherein the pan detection unit is capable of sending a response signal to the electronic control unit after the electronic control unit sends the signal to the pan detection unit to enable the pan detection unit to generate the high frequency signal through the heater element.

6. The control system of claim **5**, wherein the response signal from the pan detection unit to the electronic control unit reflects at least a portion of a reactance of the heater element.

7. The control system of claim **4**, wherein the control system further includes a user interface that is electrically connected to the electronic control unit, the user interface capable of receiving a setting from a user of the cooktop.

8. The control system of claim **4**, wherein the control system further includes a first switch device and a second switch device connected between the heater element and a power source, the first and second switch devices being electronically controlled by the electronic control unit.

9. The control system of claim **8**, wherein the first switch device is a triac.

10. The control system of claim **9**, wherein the first switch device is opened to remove the power source from the heater element when the pan detection unit generates the high frequency signal through the heater element.

11. A control system for a heating unit in a cooktop, the heating unit having a heater element, the heater element having a first terminal end and a second terminal end, the control system comprising:

a pan detection unit electrically connected to the first and second terminal ends of the heater element, the pan detection unit capable of generating a high frequency signal through the heater element to determine whether a pan is present on the cooktop; and

a switch device electrically connected between the heater element and a power source;

wherein the switch device is opened to remove the power source from the heater element when the pan detection unit generates the high frequency signal through the heater element.

12. The control system of claim **11**, wherein the cooktop has a glass-ceramic cooking surface, the heating unit and heater element mounted below the glass-ceramic cooking surface.

13. The control system of claim **11**, wherein the pan detection unit has an oscillation circuit to generate the high frequency signal through the heater element.

14. The control system of claim **11**, wherein the control system further includes an electronic control unit that is electrically connected to the pan detection unit, the electronic control unit capable of generating a signal to the pan detection unit to enable the pan detection unit to generate the high frequency signal through the heater element.

15. The control system of claim **14**, wherein the pan detection unit is capable of sending a response signal to the electronic control unit after the electronic control unit sends the signal to the pan detection unit to enable the pan detection unit to generate the high frequency signal through the heater element.

16. The control system of claim **15**, wherein the response signal from the pan detection unit to the electronic control unit reflects at least a portion of a reactance of the heater element.

17. The control system of claim **14**, wherein the control system further includes a user interface that is electrically connected to the electronic control unit, the user interface capable of receiving a setting from a user of the cooktop.

18. The control system of claim **11**, wherein the switch device is a triac.

19. A control system for a heating unit in a cooktop, the heating unit having an inner heater element and an outer heater element, the inner and outer heater elements being spirally wound wherein the inner heater element is spirally wound within the outer heater element, the control system comprising:

a pan detection unit electrically connected to the inner and outer heater elements, the pan detection unit capable of generating a high frequency signal through the inner heater element to determine whether a pan is present on the cooktop, the pan detection unit further capable of generating a high frequency signal through the outer heater element to determine a size of the pan on the cooktop;

a first switch device electrically connected between the inner heater element and a power source; and

a second switch device electrically connected between the outer heater element and the power source;

wherein the first switch device is opened to remove the power source from the inner heater element when the pan detection unit generates the high frequency signal through the inner heater element to determine whether the pan is present on the cooktop, and the second switch device is opened to remove the power source from the outer heater element when the pan detection unit generates the high frequency signal through the outer heater element to determine the size of the pan on the cooktop.

20. The control system of claim **19**, wherein the cooktop has a glass-ceramic cooking surface, the heating unit and heater element mounted below the glass-ceramic cooking surface.

21. The control system of claim **19**, wherein the pan detection unit has at least one oscillation circuit to generate the high frequency signals through the inner and outer heater elements.

22. The control system of claim **19**, wherein the control system further includes an electronic control unit that is electrically connected to the pan detection unit, the electronic control unit capable of generating a signal to the pan detection u nit to enable the pan detection unit to generate the high frequency signals through the inner and outer heater elements.

23. The control system of claim **22**, wherein the pan detection unit is capable of sending a response signal to the electronic control unit after the electronic control unit sends the signal to the pan detection unit to enable the pan detection unit to generate the high frequency signals through the inner and outer heater elements.

24. The control system of claim **23**, wherein the response signal from the pan detection unit to the electronic control unit reflects at least a portion of a reactance of either the first or second heater element.

25. The control system of claim **22**, wherein the control system further includes a user interface that is electrically connected to the electronic control unit, the user interface capable of receiving a setting from a user of the cooktop.

26. The control system of claim **19**, wherein the first switch device and second switch device are triacs.

27. A method of operating a heating unit for a cooktop with a control system that is capable of detecting whether a pan is present on the cooktop, the heating unit having a heater element, the method comprising:

receiving a setting from a user of the cooktop;

generating a high frequency signal through the heater element;

determining whether the pan is present on the cooktop from the generation of the high frequency signal through the heater element;

isolating power to the heater element if it is determined that the pan is not present on the cooktop;

providing power to the heater element if it is determined that the pan is present on the cooktop;

determining whether the pan has been removed from the cooktop after power has been provided to the heater element;

isolating power to the heater element if it is determined that the pan has been removed from the cooktop; and

providing power to the heater element if it is determined that the pan has not been removed from the cooktop.

28. The method of claim **27**, wherein the step of generating the high frequency signal through the heater element is performed by a pan detection unit having an oscillation circuit.

29. The method of claim **28**, wherein the step of determining whether the pan is present on the cooktop is performed by an electronic control unit that is electrically connected to the pan detection unit.

30. The method of claim **28**, wherein the step of determining whether the pan has been removed from the cooktop is performed by an electronic control unit that is electrically connected to the pan detection unit.

31. A control system for a heating unit in a cooktop, the heating unit having a heater element, the heater element having a first terminal end and a second terminal end, the control system comprising:

a means for receiving a setting from a user of the cooktop;

a means for generating a high frequency signal through the heater element;

a means for determining whether a pan is present on the cooktop; and

a means for isolating power to the heater element if it is determined that the pan is not present on the cooktop.

32. The control system of claim **31**, wherein the cooktop has a glass-ceramic cooking surface, the heating unit and heater element mounted below the glass-ceramic cooking surface.

33. The control system of claim **31**, wherein the means for generating the high frequency signal through the heater element includes at least an oscillation circuit.

34. The control system of claim **31**, wherein the control system further includes an electronic control unit that is electrically connected to the means for generating the high frequency signal through the heater element.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,492,627 B1
DATED : December 10, 2002
INVENTOR(S) : James W. Ensinger et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 15,
Line 23, delete "u nit" and insert -- unit --

Signed and Sealed this

Thirteenth Day of May, 2003

JAMES E. ROGAN
Director of the United States Patent and Trademark Office